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ROCKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Range Cattle Impacts on Stream Water Quality in the Colorado Front Range

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Studies on two adjacent pastures along Trout Creek in central Colorado indicated only minor effect of cattle grazing on water quality. Bacterial contamination of the water, however, significantly increased. Following removal of the cattle, bacterial counts dropped to levels similar to those in the ungrazed pasture.

Background

When cattle and other livestock are concentrated along small mountain streams, they are reported to impact the physical, chemical, and biological properties of the water. Excretion of body wastes in or near streams may add nitrogen and phosphorous compounds as well as pathogenic bacteria. Livestock trampling along streambanks may increase dissolved and suspended solids carried by streams. Heavy concentrations of cattle may also change water quality parameters to levels which will not only affect local use of water but may present health hazards to downstream users.

The purpose of this study was to determine the impact of range cattle over a short-term period on water quality, and to determine whether local grazing management practices should be changed. Data are presented for a 21-day period intensively sampled in June 1977 for the effect of 150 cows and calves concentrated along a stream typical of the Colorado Front Range.

Previous Studies

Several stream studies in Montana, Colorado, and Utah have reported the impact of grazing animals on wildland water quality (Darling 1973, Kunkle and Meiman 1967, Morrison and Fair 1966, Walter and Bottman 1967), but information on grazing effects in low-flow streams common to the Front Range of Colorado is limited. Kunkle and Meiman (1967) as well as Morrison and Fair (1966) found that bacterial counts were related to the proximity of grazing animals to the stream. Other studies have also indicated that concentrations of cattle on grasslands and pastures can contribute significant amounts of nitrogen and phosphorous compounds to surface waters,

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especially following rains and snowmelt runoff (Armstrong and Rohlich 1970, Oglesby 1971).

Study Area

The study was conducted along a 2.6-km section of Trout Creek, a perennial stream that flows through the Manitou Experimental Forest, about 13 km downstream and north of Woodland Park, Colo. The creek is a major tributary of the South Fork of the South Platte River.

The study area consisted of two adjacent pastures, each bisected by Trout Creek (fig. 1). The upper pasture was not grazed. The lower grazed pasture had 85 ha of grazable land, and the cattle had unrestricted use of the area. Each pasture had about 1.28 km of stream channel.

The flood plain in each pasture was composed of unconsolidated and coarse textured alluvium, derived from Pikes Peak granite. Unstable and easily erodable streambanks up to 2 m high are common to the area. The flood plain vegetation (about 10% of the area) consisted mainly of willows, sedges, rushes, buttercups, irises, Kentucky bluegrass, white clover, common dandelions, and various stages of weed succession (fig. 2). Vegetation in the dry upland area was mainly bunchgrass (Arizona fescue and mountain muhly) and open ponderosa pine forests.

Mean elevation of the area was about 2,357 m. Average annual precipitation is about 400 mm, with two-thirds of this amount falling during the growing season from April through September. Streamflow for the study section of Trout Creek ranges from about 0.28 m^3/sec in the spring to a low of 0.01 m^3/sec in late summer.

About 30 beavers were removed from the control pasture during the previous winter, and seven major beaver dams were breached 1 month prior to water sampling. The drained beaver ponds left broad silt flats and contributed varying amounts of sediment and organic debris to the stream. Beavers were not present in the lower

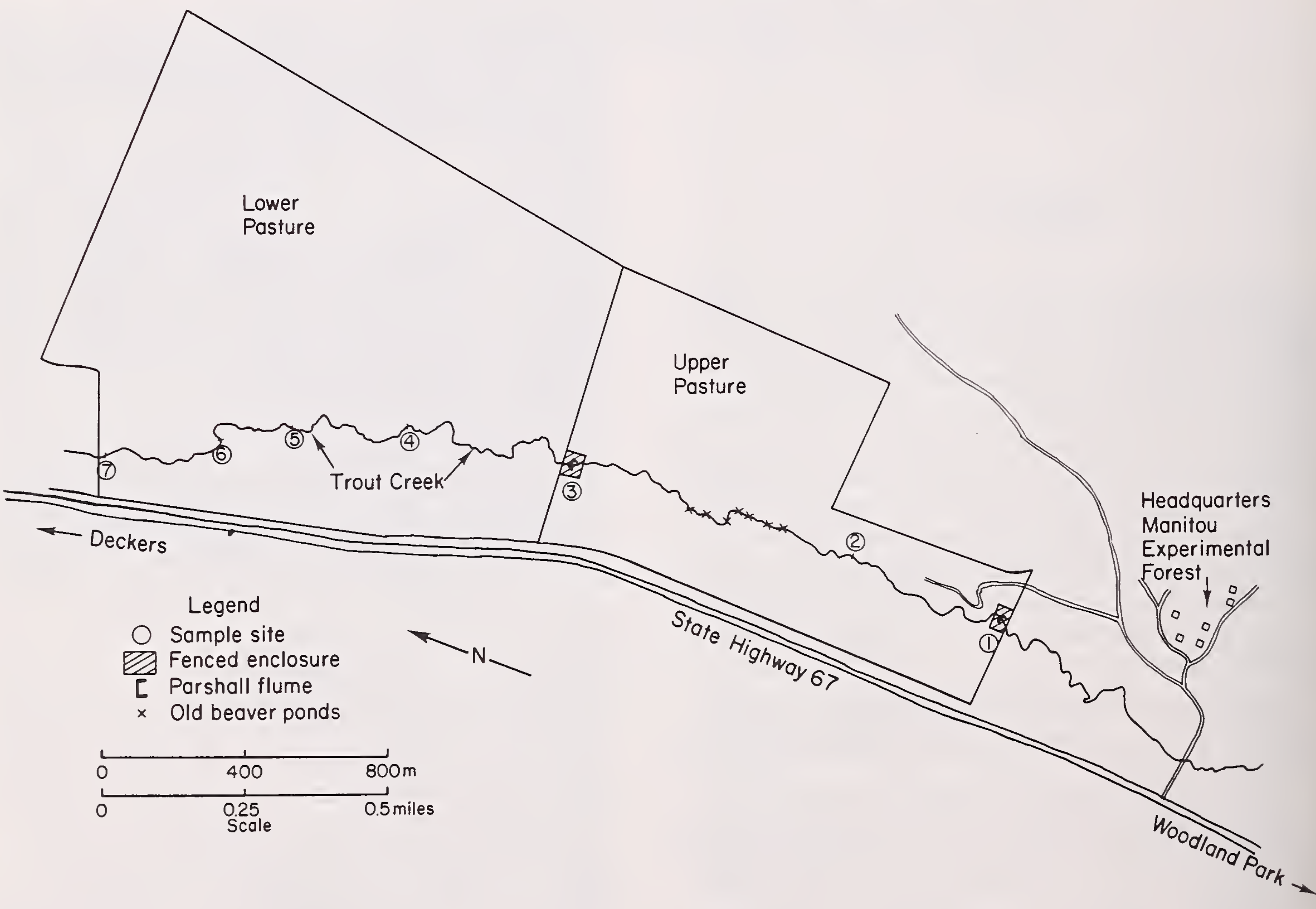

Figure 1.—Location of pastures, sampling sites and physical features of the study.

Figure 2.—The Trout Creek flood plain and the upland forest.

pasture. For the past several years, both pastures have been used only as holding areas and have been stocked with cattle from mid-April until early June, with no grazing use for the remainder of the year. The only water source is Trout Creek.

Methods

For this study, 75 cows plus 75 calves were placed in the lower pasture in early April 1977. The nearest livestock upstream from the control (ungrazed) pasture was about 3.2 km.

Water samples were collected and analyzed on six days during grazing (June 2 to 14) and on five days (June 16 to 24) when neither pasture was grazed. Three sites were sampled in the control pasture and four in the lower treatment pasture. Water analyses followed procedures outlined in *Standard Methods* (American Public Health Association, Inc. 1975) and included: dissolved oxygen, stream temperature, suspended and total dissolved solids, electrical conductivity, ammonia, nitrates, orthophosphates, and fecal coliform and fecal streptococci bacterial counts. These parameters were selected because their levels generally indicate water quality. Cattle activities and locations were observed on several days.

Stream discharge was also measured in two 48-inch Parshall Flumes equipped with stage recorders. Stream temperature, dissolved oxygen (DO), and specific electrical conductivity (EC) were measured on-site with battery operated meters. Grab samples of water were collected in sterile polyethylene bottles for all other analyses. All sampling was done during the morning, and water samples were kept iced until processing. Suspended and total dissolved solids (SS and TDS) were determined gravimetrically. Ammonia nitrogen (NH_3-N), nitrate nitrogen (NO_3-N) and orthophosphate (PO_4) measurements were made colormetrically following filtration to remove turbidity interference. The respective tests were made using prepackaged reagent powder pillows along with other reagents. Bacterial culturing was routinely completed within 2 hours of the first sample collection using the membrane filter technique and several dilutions per sample.

All data were analyzed using a two-way analysis of variance of pastures and sampling days. Minimum significance for acceptance of hypothesis of no difference was the 0.05 level. Comparison of pooled pasture means (sites 1, 2, 3 and sites 4, 5, 7) were made both during and after the grazing period as a test of grazing effects. Data from sites 5 and 6 were averaged to balance the variance analysis.

Results and Discussion

Cattle Activities

The cattle generally grouped along the flood plain within about 400 m of the stream during the day, but tended to disperse and move into the warmer uplands at night. Visual observations during this and in other studies indicated the cattle generally spent considerably less than 1% of the day in the stream drinking or resting (Dwyer 1961). Thus, the probability of elimination of body wastes into the stream was low.

Stream Temperature and Dissolved Oxygen

Stream temperatures generally ranged between 13° and 18°C during sampling. The range was mainly due to an hour time lapse between collection of the first and last water samples. Dissolved oxygen, because of the turbulent nature of the stream, was at or near saturation for all sites for the duration of the study.

Suspended Solids and Streamflow

High concentrations of suspended solids (SS) are generally an indication of erosion and are usually associated with the degree of impact of man's activities. Waters having average SS concentrations above 80 mg/l generally harm fish and other aquatic life (McKee and Wolf 1963). The most common sources of SS in the local area were ero-

sion from bank sloughing and from abandoned and washed out beaver dams.

In the present study, the innumerable stream crossings by cattle between sites 4 to 7 did not significantly increase SS (table 1). SS concentrations ranged from 3 to 183 mg/l. The source of SS was mainly the silt and organic debris stored in the former beaver ponds between study sites 2 and 3 in the upper pasture (fig. 3). Sites 1 and 2 in the upper pasture showed relatively low levels of SS for the period of grazing. ~~The~~ high SS shown for the grazed pasture on July 10, during peak June 10 streamflow, evidently originated from the former beaver dams in the upper pasture. The high amounts of SS were apparently transported downstream and through the grazed pasture, and there was little evidence the cattle further added significant amounts of SS in the period of high streamflow.

Following grazing, streamflow averaged about 0.06 m^3/sec, and SS were generally less than 10 mg/l at all sites except for site 3, which averaged about 15 mg/l. It will probably be a few years before all sediments are flushed out and/or stabilized in the beaver pond areas between sites 2 and 3.

Total Dissolved Solids and Specific Conductance

All natural stream waters contain dissolved solids. Common ions in solution include carbonates, bicarbonates, chlorides, sulfates, phosphates, and nitrates of calcium, magnesium, sodium and potassium. Total dissolved solids (TDS) and specific electrical conductivity (EC) of natural waters are lowered by rainfall or snowmelt water (Tiedeman 1974) and raised by the addition of wastewater effluents, and runoff from feedlots and fertilized fields and pastures.

In this study, TDS were considerably less than the lower threshold value of about 400 mg/l reported for productive waters (McKee and Wolf 1963). The cattle had no significant effect on TDS or EC during the period of grazing. The significant difference in TDS between pastures after grazing (table 1) may indicate that some livestock waste products eventually reached and enriched the stream, probably from the action of rain showers.

Ammonia and Nitrate Nitrogen

In rural areas, much like the study area, NH_3-N and NO_3-N generally originate either from leakage of septic tanks and effluents from waste treatment plants, runoff from barnyards and feedlots, or runoff from fertilized pastures and croplands.

NH_3-N is readily oxidized to NO_3-N under aerobic conditions, and in unpolluted streams, concentrations are generally less than 0.2 mg/l (McKee and Wolf 1963). The average concentrations of NH_3-N for the periods of measurement on Trout Creek ranged from 0.26 to 0.29 mg/l in the ungrazed and grazed pastures respectively (table 1).

NO_3-N, the most completely oxidized and most stable form of nitrogen in surface waters, is a natural fertilizer and generally stimulates the growth of aquatic plants and increases fish production. Average concentrations of NO_3-N during

Table 1.—Mean values from the two pastures during and after grazing for selected water quality parameters.

Parameter	June 2 through June 14			June 16 through June 24		
	Upper pasture (no grazing)	Lower pasture (grazed)	Diff.	Upper pasture (no grazing)	Lower pasture (no grazing)	Diff.
Suspended solids (SS) mg/l	34.2	63.4	29.2	9.8	7.8	2
Total dissolved solids (TDS) mg/l	152	152	0	139	142	[2]3
Specific electrical conductivity (EC) μmhos/cm	209	211	2	221	224	3
Ammonia nitrogen (NH_4-N) mg/l	.26	.27	.01	.26	.29	.03
Nitrate nitrogen (NO_3-N) mg/l	.30	.36	.06	.13	.13	.00
Orthophosphates (PO_4) mg/l	.20	.22	.02	.20	.18	–.02
Fecal coliforms (FC) colonies/100 ml	20	105	[1]85	21	44	23
Fecal streptococci (FS) colonies/100 ml	73	176	[1]103	210	323	113

[1]*Statistically significant at 0.05 level*
[2]*Statistically significant at 0.01 level*

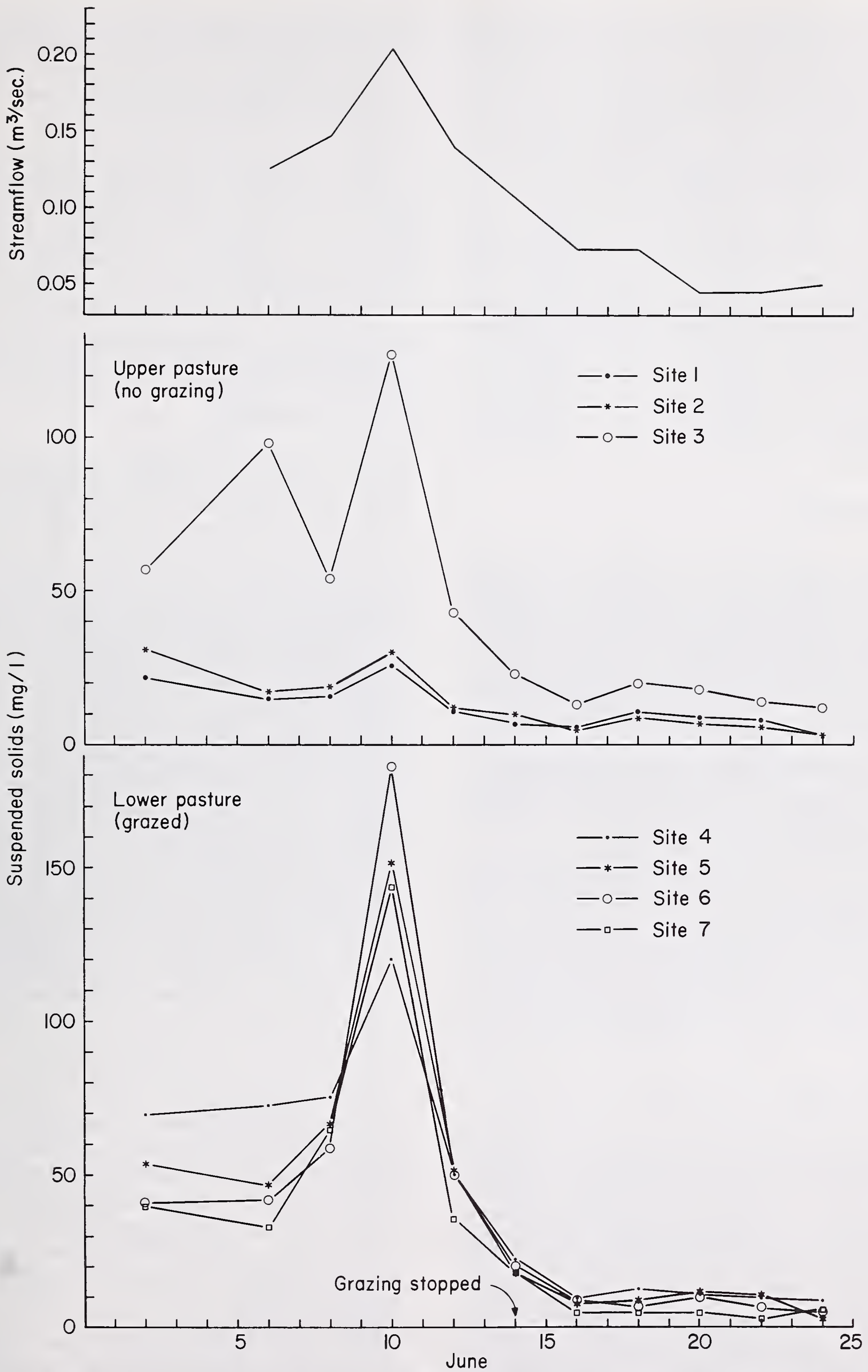

Figure 3.—Streamflow and suspended solids (SS) for each sampling site in the upper and lower pastures.

the period of grazing ranged from 0.30 to 0.36 mg/l in the ungrazed and grazed pastures, respectively (table 1). In the period of no grazing, the concentration of NO_3-N averaged 0.13 mg/l in both pastures (table 1). The higher nitrate concentrations during the period of grazing coupled with higher streamflow during the period were believed to indicate a spring "flush out" of accumulated nitrate compounds from upstream banks. The concentration of NO_3-N for both study periods was relatively low and appeared to indicate only minor input from upstream sources. The presence of cattle in the lower pasture did not significantly increase NO_3-N levels. All observed concentrations were well below the maximum permissible level of 10 mg/l of NO_3-N for domestic water supplies (U.S. Environmental Protection Agency 1975).

Orthophosphates

Phosphorous is also an essential nutrient for both plants and animals, but excessive amounts in stream and lake water may result in overabundant aquatic plant growth, such as algae blooms. The major sources of phosphorous, other than geologic weathering, are runoff from feedlots, excessive applications of phosphate fertilizers and insecticides, and sewage effluents (U.S. Environmental Protection Agency 1976). Detergents containing phosphates are a minor source of phosphorous pollution, but the use of phosphates in cleaning compounds is decreasing.

The presence of cattle in the lower pasture did not significantly increase the concentration of orthophosphates (table 1). The average concentration was about 0.2 mg/l in both pastures. Orthophosphate concentrations below 0.2 mg/l do not generally cause undesirable enrichment and aquatic plant growth in streams (McKee and Wolf 1963).

Bacteriologic Parameters

Bacterial tests of water pollution are usually performed by culturing and counting a group of bacteria known collectively as coliform bacteria. These bacteria are always present in intestinal tracts of warm blooded animals and are eliminated in large numbers in fecal waste. The indicator bacteria are not usually pathogenic themselves and do not generally multiply outside the intestines but are often found in the company of intestinal pathogens affecting man and other mammals. Thus, their presence indicates that intestinal waste products have reached a stream water supply. Water supplies containing coliform densities greater than one colony/100 ml are generally unacceptable for domestic use (U.S. Environmental Protection Agency 1975).

All species of animals have generally characteristic proportions of fecal coliform (FC) and fecal streptococci (FS). Thus, the FC/FS ratios have been established to identify the source of pollution as human or non-human warm-blooded animal polluted (Kenner et al. 1960). When the ratio is greater than about 2.5, the source of fecal organisms is predominantly human wastes. Ratios less than about 1.0 usually indicate that domestic livestock and other animals are the source of pollution.

The FC and FS counts and ratios from the present study are given in table 2. All FC/FS ratios were less than 1.0 and appear to indicate that bacterial contamination was derived from non-human sources. In both study periods, FC and FS counts in the upper ungrazed pasture were relatively high and suggested that bacterial pollution was mainly due to small mammals and birds, since no cattle or people were in the immediate upstream area. The presence of the grazing cattle significantly elevated the FC and FS counts over those observed in the ungrazed pasture (table 1). After removal of the cattle, both FC and FS bacterial counts dropped to statistically non-significant levels within the 9-day study period following grazing. Because of wide fluctuation in FS bacteria counts, there were also significant differences among sampling days following grazing. This was expected, since widely variable bacterial counts are characteristic of most wildland streams and are greatly affected by rainy periods (Kunkle and Meiman 1967).

Conclusions

In the last 100 years, most of the meadows along the perennial streams in the Front Range of Colorado have been heavily used by cattle and other livestock. Undoubtedly, due to the large numbers of animals (some 300,000 head in 1950 (Gary 1975)), the quality of most streams has been impacted to some degree by livestock waste products.

The measured physical and chemical properties of streamflow in this study indicated minor pollution from unknown upstream sources. These findings, however, do not provide significant evidence

Table 2.—Mean fecal coliform (FC) counts, fecal streptococci (FS) counts, and FC/FS ratios for the periods of grazing and no grazing.

Date Sampled	Sites 1-3 Upstream control pasture[1]			Sites 4-7 Downstream grazed pasture[2]		
	FC	FS	FC/FS	FC	FS	FC/FS
	Colonies/100 ml			Colonies/100 ml		
6-2	3	52	0.058	58	119	0.487
6-6	14	52	.069	38	83	.458
6-8	38	100	.380	149	157	.949
6-10	41	77	.532	192	252	.762
6-12	7	88	.080	58	119	.487
6-14	19	66	.288	136	330	.412
6-15	All cattle removed from downstream pasture					
6-16	7	46	.152	37	128	.289
6-18	19	131	.145	84	552	.152
6-20	18	102	.176	25	163	.153
6-22	21	159	.132	21	188	.112
6-24	41	610	.067	55	585	.094

[1]*No cattle in pasture during study.*
[2]*150 cow-calves in pasture.*

of major long-term cumulative impairment of water quality due to past grazing practices in the area. The pasture comparisons provided some insight as to the immediate effects of grazing. At stocking rates of about 1.2 ha of usable pasture per cow plus calf pair, a rate locally common for short-term, seasonally grazed pastures, there were no statistically significant differences in the physical and chemical properties of the stream water that could be attributed to the grazing cattle. However, the cattle contributed significantly to the bacterial contamination of the stream, but after removing the cattle, bacterial counts dropped to levels similar to those in the ungrazed pasture within a short time.

Today, range cattle (cows) number only about 122,000 head in the counties along the Front Range in Colorado or about 13% of the total number for the State.[3] Thus, the regional potential of livestock wastes contaminating streams along the Front Range has also been greatly reduced from earlier years and permanent removal of the cattle from the productive live stream flood plains does not appear justified.

Literature Cited

American Public Health Association, Inc. 1975. Standard methods for the analysis of water and wastewater. 14th ed. 874 p. Am. Public Health Assoc., Inc., New York, N.Y.

[3]*Personal communication with Dr. C. K. Gee, USDA Economic Research, February 1978, Fort Collins, Colo.*

Armstrong, D. E. and G. A. Rohlich. 1970. Effects of agricultural pollution on eutrophication. p. 314-330. *In* Agricultural practices and water quality. T. E. Willrich and G. E. Smith, eds., Iowa State Press, Ames.

Darling, L. A. 1973. The effects of livestock grazing on wildland water quality. M.S. Thesis, Utah State Univ., Logan. 99 p.

Dwyer, D. D. 1961. Activities and grazing preference of cows and calves in northern Osage County, Oklahoma, Okla. Agric. Exp. Stn. Bull. B-588, 61 p. Stillwater.

Gary, Howard L. 1975. Watershed management problems and opportunities for the Colorado Front Range ponderosa pine zone: The status of our knowledge. USDA For. Serv. Res. Pap. RM-139, 32 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Kenner, B. S., H. F. Clark and P. W. Kabler. 1960. Fecal streptococci. 1. Quantification in feces. Am. J. Public Health 50:1553-1559.

Kunkle, Samuel H. and James R. Meiman. 1967. Water quality of mountain watersheds. Colo. State Univ. Hydrol. Pap. No. 21, 53 p. Colo. State Univ., Fort Collins.

McKee, Jack Edward and Harold W. Wolf, eds. 1963. Water quality criteria. Calif. State Water Resour. Control Board, Publ. 3-A (revised) 548 p. Sacramento.

Morrison, S. M. and J. F. Fair. 1966. Influence of environment on stream microbial dynamics. Colo. State Univ. Hydrol. Pap. No. 13, 21 p. Colo. State Univ., Fort Collins.

Oglesby, R. T. 1971. Farm land runoff. p. 15-19. *In* Agricultural wastes; Principles and guidelines for practical solutions. Cornell Univ. Conf. on Agric. Waste Manage. [Syracuse, N.Y., Feb. 11-12, 1971] Cornell Univ., Ithaca, N.Y.

Tiedemann, R. A. 1974. Stream chemistry following a forest fire and urea fertilization in North Central Washington. USDA For. Serv. Res. Pap. PNW-203, 20 p. Pac. Northwest For. and Range Exp. Stn., Portland, Oreg.

U.S. Environmental Protection Agency. 1975. Interim primary drinking water stands. Fed. Regist. 40(51):11990-11998. Washington, D.C.

U.S. Environmental Protection Agency. 1976. Water quality and pollutant source monitoring: Field and laboratory procedure training manual, EPA-430/1-76-010. U.S. Environ. Protect. Agency, Off. of Water Program Oper., Cincinnati, Ohio.

Walter, W. G., and R. P. Bottman. 1967. Microbiological and chemical studies of an open and closed watershed. J. Environ. Health 30:157-163.

ERRATA SHEET

The following error has been noted in Research Note RM-359, "Range cattle impacts on stream water quality in the Colorado Front Range."

p. 4, left column, line 12, "July 10" should be "June 10".